Time-Independent Perturbation Theory

Physics 541 Homework Set 5

Due May 21, 2003

Two "Simple" TIPT Problems

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1. Reconsider the electron in a quantum well problem that we discussed in class; please see the "Quantum Well" section of the Virtual Book for the complete details.

(a) Calculate the first-order corrections to the eigenenergy E_2. Calculate the amplitudes a_j of the two largest corrections to the unperturbed wavefunction $|2>$.

(b) Calculate the first-order corrections to the eigenenergy E_3. Calculate the amplitudes a_j of the two largest corrections to the unperturbed wavefunction $|3>$.

Hint: With the aid of diagrams, make a geometrical analysis of the problem, exploiting the symmetry, before doing any quantitative calculations. These are problems 7.1 and 7.2 in the "Quantum Well" section.

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2. Consider the perturbed simple-harmonic oscillator described by the Hamiltonian $H = H_0 + H_1$ where

$$H_0 = \frac{p^2}{2m} + \frac{1}{2}\, kx^2$$

$$H_1 = a\, x^6$$

(a) Calculate the first-order corrections to the eigenenergies E_n of the unperturbed oscillator produced by this perturbation.

(b) Calculate the first- and second-order corrections to the wavefunctions $|n>$ of the unperturbed oscillator produced by this perturbation.

This problem is very similar to Schaum's problems 10.3, 10.18, 10.19, and 10.20. Can you see how to extend your solution to the general case $H_1 = a\, x^n$? How about to the other general case $H_1 = a\, |x^n|$?

Two "Exotic Hydrogen Atom" TIPT Problems

The muonic hydrogen atom consists of a negative muon electrostatically bound to a positive proton. The mass of the muon is 206.77 times the mass of the electron. The charge and the g-factor of the muon are identical to the electron. Before you start using TIPT, calculate the new reduced mass, the new Bohr radius, and the new energy scale for muonic hydrogen.

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3. Use TIPT to calculate the Stark effect for the $n = 2$ states of muonic hydrogen.

This problem is very similar to Schaum's problem 10.10 and to Griffith's problem 6.26.

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4. Use TIPT to calculate the Zeeman effect for the $n = 1$ hyperfine-split states of muonic hydrogen.

The zero magnetic field hyperfine splitting for muonic hydrogen is 4463.317 ± 0.021 MHz, instead of 1420405751.768 ± 0.001 Hz for good old hydrogen. For the complete details, please see the "Hyperfine" section of the Virtual Book; this problem is related to Griffith's problem 6.31.
